HL 99: Gallium Nitride: Devices

Time: Friday 9:30–12:30 Location: H17

Invited Talk HL 99.1 Fri 9:30 H17

Multifunctional 3D GaN: strategies for solid state lighting, electronics and sensing — •Andreas Waag[1,4,5], J. Hartmann[1,4], Hao Zhou[1], S. Fündling[1,4], F. Steib[1,4], M. Mohajerani[1], Feng Yu[1], H.-H. Wehmann[1,4], A.E. Gad[1], D. Prades[6], D. Bichler[2], B. Huckenbeck[2], T. Schimpke[3], M. Mandl[3], I. Stoll[3], A. Avramescu[3], M. Strassburg[3], and H.-J. Lugauer[3] — [1]Institut für Halbleitertechnik, TU Braunschweig — [2]OSRAM GmbH, Schwabmünchen — [3]OSRAM Opto Semiconductors GmbH, Regensburg — [4]Epitaxy Competence Center ec2, Braunschweig — [5]Laboratory for Emerging Nanometrology LENA, Braunschweig — [6]Department of Electronics, University of Barcelona

GaN nanorods and related high aspect ratio 3D GaN nanostructures recently attracted a lot of attention since they are expected to be an exciting new route towards extending the freedom for device design in GaN technology. Such structures offer large surfaces, defect free high quality material, as well as non-polar surface orientations, including the possibility to use very large area foreign substrates without implementing large area strain. All of these aspects are difficult or impossible to achieve when planar thin film approaches are used. This talk will give an overview on the state of the art of our 3D GaN research, pointing out the necessity for further epitaxy related research, but also describing the increasingly interesting demonstration of 3D devices like 3D LEDs, 3D nanoFETs and 3D nanosensing devices, and their substantial potential for solid state lighting, power electronics and nanometrology.

HL 99.2 Fri 10:00 H17

Photon Statistics of high–β Nitride Nanobeam Lasers — •Stefan T. Jagsch[1], Noelia Vico Triviño[2], Gordon Callsen[1], Stefan Kalinowski[1], Ian M. Rousseau[2], Jean-François Carlin[2], Raphaël Butté[2], Axel Hoffmann[1], Nicolas Grandjean[2], and Stephan Reitzenstein[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, D-10623 Berlin, Germany — [2]Institute of Condensed Matter Physics, École Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

1D photonic crystal nanobeam cavities feature an ultra–low mode-volume and are thus exciting candidates for the realization of low threshold and high spontaneous emission coupling factor (β) nanolasers. Of particular interest are GaN based nanobeam lasers because they promise room–temperature operation, which is highly attractive from a practical perspective. Promising applications include for instance on–chip silicon integrated photonics [1]. Herein we present a comprehensive temperature dependent quantum optical characterization of continuous wave lasing in a high–β III–nitride nanobeam cavity grown on silicon. In the present structures, with β–factors close to unity, the onset of stimulated emission can hardly be identified from the sole I-O characteristics. Indeed, we show that the analysis of the photon statistics is required to reveal a threshold behaviour. Our results highlight the importance of determining the photon statistics of emission to unambiguously determine the onset of lasing in nanolasers. [1] Triviño et al., Nano Lett. 15 (2), 1259, 2015

HL 99.3 Fri 10:15 H17

Blue LED optimization based on a MOCVD growth parameter sensitivity study — •Michael Heuken, Egidijus Sakalauskas, Xiaojun Chen, Olivier Feron, Hannes Behmenburg, Ralf Leiers, Markus Luenenbuerger, Peter Lauffer, Adam Boyd, and Johannes Lindner — AIXTRON SE, Dornkaulstr 2, 52134 Herzogenrath, Germany m.heuken@aixtron.com

The most important dependencies such as LED wavelength dependence on surface temperature, ammonia flow, group III molar flow, total flow and total pressure was experimentally determined for a state of the art production reactor. Experimentally obtained temperature sensitivity data serve as input to simulate, understand and finally improve the uniformity and performance of LED. Average system uptime higher than 90% is obtained based on routine maintenance procedures with more than 3 production runs per day in a production process flow for competitive LED products. The measured dependencies and the equipment optimizations result in wavelength uniformity of full susceptor load consisting of 4 inch DPSS wafers of 91.8% for a 6nm bin yield centred at 443nm. In a multi growth campaign utilizing 5 runs with 4 inch DPPS wafer loaded the run to run wavelength stability was assessed. On-wafer uniformity is stable with an average standard deviation of 1.48 nm. R2R wavelength standard deviation of 0.23 nm was observed for this series indicating less than 0.2 C standard deviation in average QW temperature. Loading 12 wafer with 6 inch diameter enable additional productivity gains demonstrated as standard deviation in QW emission wavelength of σ=4.5nm.

HL 99.4 Fri 10:30 H17

Impact of Design on the Optical Polarization of AlGaN Quantum Well Deep UV Light Emitters — •Christoph Reich[1], Martin Feneberg[2], Martin Guttmann[1], Frank Mehnke[1], Tim Wernicke[1], and Michael Kneissl[1] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Berlin, Germany — [2]Otto-von-Guericke-Universität Magdeburg, Institut für Experimentelle Physik, Magdeburg, Germany

Light emitting diodes in the deep ultraviolet spectral region are of significant interest for applications in a variety of fields. However, efficient light extraction is a challenging task for deep UV emitters due to the strong tendency for transverse magnetic (TM, $\boldsymbol{E} \parallel \boldsymbol{c}$) polarized emission at shorter wavelength. The emission pattern for TM-polarized light is in-plane and thus the light extraction of TM-polarized light through a (0001) surface is an order of magnitude weaker compared to transverse electric (TE, $\boldsymbol{E} \perp \boldsymbol{c}$) polarized light. The optical polarization of (0001) oriented AlGaN quantum wells shifts from TE to TM with increasing aluminum mole fraction due to a reordering of valence bands and changing oscillator strengths. Using $\mathbf{k}\cdot\mathbf{p}$ perturbation theory, the influence of strain, quantum well width, barrier height and composition on the optical polarization has been investigated. The theoretical model calculations showed that compressive strain in the growth-plane and barriers with high aluminum mole fraction are beneficial for enhanced TE-polarized emission. Based on these design parameters, dominant TE emission will be demonstrated at wavelengths as short as 240 nm.

HL 99.5 Fri 10:45 H17

Radiative recombination and parasitic luminescence in AlGaN-based UVC-LEDs — •Simon Kapanke[1], Johannes Enslin[1], Frank Mehnke[1], Christian Kuhn[1], Martin Guttmann[1], Christoph Reich[1], Ute Zeimer[2], Tim Wernicke[1], Markus Weyers[2], and Michael Kneissl[1,2] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Berlin — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin

Ultraviolet (UV) light emitting diodes (LEDs) exhibit significant advantages compared to conventional UV light sources such as low power consumption and adjustable wavelength. Interesting applications for UVC-LEDs are compact gas sensing systems. However, achieving the required output power levels and high spectral purity is challenging. In this contribution, we present our recent investigations on the origin of parasitic luminescence observable in the electroluminescence measurements of AlGaN multiple quantum well LEDs emitting at 233 nm. The origin of the parasitic emission was located within the p-side of the LED heterostructure and analyzed by photoluminescence and cathodoluminescence measurements. Therefore, the Al-content in the p-side superlattice was varied resulting in a shift of the two main contributions of the parasitic luminescence towards shorter wavelength for higher Al-content. Additionally a reduced Mg-concentration in the p-side of the LEDs results in a reduced parasitic luminescence intensity indicating Mg-related deep level transitions to be involved as observed by Nakarmi et al. A detailed discussion of the experimental findings together with a comparison to recent literature will be provided.

30 min. Coffee Break

HL 99.6 Fri 11:30 H17

Carbon doping of GaN using propane for compensation of n-type GaN layers — •Andreas Lesnik, Marc Hoffmann, Jonas Hennig, Aqdas Fariza, Jürgen Bläsing, Hartmut Witte, Armin Dadgar, and André Strittmatter — Institut für Experimentelle Physik, Otto-von-Guericke-Universität Magdeburg

We investigated propane as source for intentional carbon doping of GaN using metalorganic vapor-phase epitaxy (MOVPE). The effect

of carbon incorporation on structural and electrical parameters was studied in the concentration range of 1x10e^{17}-5x10e^{18} cm^{-3}. Carbon doping using propane leads to highly resistive GaN layers. In order to analyze the compensation efficiency of carbon for n-type GaN layers a Si+C co-doping technique was applied. Resistance and Hall effect measurements at room temperature reveal the persistence of the compensation effect over the whole doping range. Further structural analysis was done by secondary ion mass spectroscopy measurements, high-resolution x-ray diffraction, and atomic force microscopy.

HL 99.7 Fri 11:45 H17

Impact of buffer structure on the performance of AlInN/GaN based FETs grown on Si (111) — •Jonas Hennig, Armin Dadgar, Jürgen Bläsing, Annette Dietz, and André Schrittmatter — Otto-von-Guericke Universität,Magdeburg

We present a study on the impact of SiN masks as well as the influence of AlN interlayers on the performance of AlInN/GaN field effect transistors grown on Si(111). Characteristic device parameters such as breakdown voltage, on-resistance, and buffer leakage are analysed with respect to the quality of the underlying buffer structure. Buffer structures on Si(111) substrates are usually optimized for controlling stresses and the dislocation density in the structure. This is on one hand necessary to enable a compensation of thermal stresses which arise after growth during cooling down to room-temperature. On the other hand, device parameters of FET structures improve with reduction of the dislocation density. We have investigated different AlGaN/GaN buffer structures in combination with low-temperature grown AlN interlayers and in-situ deposited SiN-masks for optimum performance of the FET devices.

HL 99.8 Fri 12:00 H17

Smooth and uniform $Al_{0.8}Ga_{0.2}N$:Si superlattice cladding layers for UV-C laser diodes — •C. Kuhn[1], T. Simoneit[1], M. Martens[1], F. Mehnke[1], J. Enslin[1], K. Bellmann[1], A. Knauer[2], T. Wernicke[1], M. Weyers[2], and M. Kneissl[1,2] — [1]Technische Universität Berlin, Institut für Festkörperphysik, Berlin, Germany — [2]Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, Berlin, Germany

For deep UV laser diodes the current injection, light absorption and waveguiding are key challenges. For efficient waveguiding smooth and abrupt interfaces are required, to avoid losses associated with light scattering. This paper investigates the influence of the growth process on the morphology and the conductivity of $Al_{0.8}Ga_{0.2}N$:Si n-cladding layers. We recently demonstrated highly conductive n-AlGaN single layers with sheet resistance of 0.026 Ωcm. However, these AlGaN layers exhibited relatively rough morphologies with large spirals of 30 nm height caused by the high growth rates. Additionally $Al_xGa_{1-x}N$:Si layers with $x \leq 0.8$ exhibit noticeable compositional fluctuations. In this paper we explore the use of AlGaN super lattices (SL), as well as growth interruptions (GRI) between the SL layers in order to reduce the roughness of the surface. XRD measurements exhibit well-ordered growth of the 2 nm/2 nm thick SL layers with average composition of x=0.8 and distinct satellite peaks in the XRD spectrum, without any indication for compositional fluctuations. The RMS roughness on 10x10 μm^2 decreases from 7.0 nm without SL, to 3.7 nm with SL and 2.5 nm with 10 s GRI and obtaining the high conductivity constant.

HL 99.9 Fri 12:15 H17

Impact of a GaN:Ge/GaN based distributed Bragg reflector on the optical properties of an InGaN LED structure — •Andreas Voss, Gordon Schmidt, Christoph Berger, Stefan Sterling, Frank Bertram, Armin Dadgar, André Strittmatter, and Jürgen Christen — Institute of Experimental Physics, Otto-von-Guericke-University Magdeburg, Germany

The Burstein-Moss effect as present in highly Ge-doped GaN leads to a reduction of the refractive index of GaN:Ge as compared to undoped GaN. The resulting refractive index contrast of 2% is sufficient to realize strain free, highly reflective, and narrow band distributed Bragg reflectors (DBR) by combining highly Ge-doped and undoped GaN quarter-wavelength layers.

We report on the optical properties of an InGaN LED structure grown on top of a modulation-doped DBR by metal-organic vapor phase epitaxy (MOVPE) using an AlGaN/sapphire template. The DBR consists of 100 pairs GaN/GaN:Ge $\lambda/4$ layers. An InGaN/GaN multiple quantum well embedded in a pn-junction acts as active region.

Spatially resolved electroluminescence (EL) measurements exhibit a convolution of the MQW luminescence with the DBR reflectivity which leads to a drastically reduced linewidth at 430 nm. Detailed analysis of the local reflectivity on micrometer scale reveals spatial fluctuations of the stopband position.